PCT/GB 99 / 02482

The Patent Office

REC'D 15 SEP 1999

WIPO PCT

INVESTOR IN PEOPLE

The Patent Office
Concept House
Cardiff Road
Newport
South Wales
NP10 8QQ

GB 99/2482

09/744709

I, the undersigned, being an officer duly authorised in accordance with Section 74(1) and (4) of the Deregulation & Contracting Out Act 1994, to sign and issue certificates on behalf of the Comptroller-General, hereby certify that annexed hereto is a true copy of the documents as originally filed in connection with the patent application identified therein.

In accordance with the Patents (Companies Re-registration) Rules 1982, if a company named in this certificate and any accompanying documents has re-registered under the Companies Act 1980 with the same name as that with which it was registered immediately before re-registration save for the substitution as, or inclusion as, the last part of the name of the words "public limited company" or their equivalents in Welsh, references to the name of the company in this certificate and any accompanying documents shall be treated as references to the name with which it is so re-registered.

In accordance with the rules, the words "public limited company" may be replaced by p.l.c., plc, P.L.C. or PLC.

Re-registration under the Companies Act does not constitute a new legal entity but merely subjects the company to certain additional company law rules.

Signed

Dated 27 August 1999

PRIORITY DOCUMENT

SUBMITTED OR TRANSMITTED IN COMPLIANCE WITH RULE 17.1(a) OR (b)

Patents Form 1/77

s Act 1977
16)

The Patent Office

30JUL98 E379447-12 D02884
P01/7700 25.00 - 9816490.8

Request for grant of a patent

(See the notes on the back of this form. You can also get an explanatory leaflet from the Patent Office to help you fill in this form)

The Patent Office

Cardiff Road
Newport
Gwent NP9 1RH

1.	Your reference	P22231/CPA/RMC
2.	Patent application number *(The Patent Office will fill in this part)*	29 JUL 1998 **9816490.8**
3.	Full name, address and postcode of the or of each applicant *(underline all surnames)*	The Court of Napier University Colinton Road EDINBURGH EH10 5DT
	Patents ADP number *(if you know it)*	7035681001
	If the applicant is a corporate body, give the country/state of its incorporation	UK
4.	Title of the invention	"Fluorescent Fibres"
5.	Name of your agent *(if you have one)*	Murgitroyd & Company
	"Address for service" in the United Kingdom to which all correspondence should be sent *(including the postcode)*	373 Scotland Street GLASGOW G5 8QA
	Patents ADP number *(if you know it)*	1198013

6. If you are declaring priority from one or more earlier patent applications, give the country and the date of filing of the or of each of these earlier applications and *(if you know it)* the or each application number

Country	Priority application number *(if you know it)*	Date of filing *(day / month / year)*

7. If this application is divided or otherwise derived from an earlier UK application, give the number and the filing date of the earlier application

Number of earlier application	Date of filing *(day / month / year)*

8. Is a statement of inventorship and of right to grant of a patent required in support of this request? *(Answer 'Yes' if:*
a) any applicant named in part 3 is not an inventor, or
b) there is an inventor who is not named as an applicant, or
c) any named applicant is a corporate body.
See note (d))

Yes

9. Enter the number of sheets for any of the following items you are filing with this form. Do not count copies of the same document

Continuation sheets of this form	
Description	8
Claim(s)	
Abstract	
Drawing(s)	5 + 5

10. If you are also filing any of the following, state how many against each item.

Priority documents	
Translations of priority documents	
Statement of inventorship and right to grant of a patent *(Patents Form 7/77)*	
Request for preliminary examination and search *(Patents Form 9/77)*	
Request for substantive examination *(Patents Form 10/77)*	
Any other documents *(please specify)*	

11. I/We request the grant of a patent on the basis of this application.

Signature Murgitroyd & Company Date 28/7/98
Murgitroyd & Company

12. Name and daytime telephone number of person to contact in the United Kingdom: Roisin McNally, 0141 307 8400

Warning

After an application for a patent has been filed, the Comptroller of the Patent Office will consider whether publication or communication of the invention should be prohibited or restricted under Section 22 of the Patents Act 1977. You will be informed if it is necessary to prohibit or restrict your invention in this way. Furthermore, if you live in the United Kingdom, Section 23 of the Patents Act 1977 stops you from applying for a patent abroad without first getting written permission from the Patent Office unless an application has been filed at least 6 weeks beforehand in the United Kingdom for a patent for the same invention and either no direction prohibiting publication or communication has been given, or any such direction has been revoked.

Notes

a) *If you need help to fill in this form or you have any questions, please contact the Patent Office on 0645 500505.*

b) *Write your answers in capital letters using black ink or you may type them.*

c) *If there is not enough space for all the relevant details on any part of this form, please continue on a separate sheet of paper and write "see continuation sheet" in the relevant part(s). Any continuation sheet should be attached to this form.*

d) *If you have answered 'Yes' Patents Form 7/77 will need to be filed.*

e) *Once you have filled in the form you must remember to sign and date it.*

f) *For details of the fee and ways to pay please contact the Patent Office.*

TITLE

Fluorescent dye doped polymer optical fibres for energy saving illumination and display applications

FIELD

The present invention relates to fluorescent dye doped optical fibres and in particular display and illumination devices which are based on these fibres.

DISPLAY TECHNOLOGY

This invention relates to display technology. Fluorescent dye doped polymer fibres can be used to collect ambient light. By introducing red, green and blue light emitting fluorescent dyes into the polymer host material, the colour of the emitted light at the end of the fibre can be changed into the required specification. By a suitable combination of the optical fibre geometry (length and diameter) and the appropriate fluorescent dye, the light power density at the end of the fibre (light emitter) can be made much larger than the light power density of the ambient light and therefore can be used for illumination or display applications. Furthermore, the contrast between the light power density at the end of the fibre and the light power density of the ambient light remains constant because this parameter does only depend on the geometrical and material parameters for a given fibre but does not depend on the ambient light conditions. The end of the fibres can be used as light emitting pixels in an array. By modulating the light intensity at the end of each fibre selectively, the fibre array can be used as a display device.

HISTORY

In this field it is already known that optical fibres can be used to convey information either in telecommunication or in display technology.

But this has the disadvantage that

the light is generated by applying external electrical power and converting this electrical power into light power and consequently this method comsumes electrical power

It is an object of the present invention to provide improved optical fibres for use in illumination and display applications.

According to the present invention there is provided fluorescent dye doped optical fibres for use in visual display comprising a optically transparent polymer doped with organic fluorescent dye molecules wherein fluorescent light is generated when artificial ambient light, daylight or sunlight enters the fibres.

Whereas in general any transparent polymer may be used, suitably the transparent polymer is chosen from the group comprising PMMA, polycarbonate and polystyrene.

Whereas in general any organic fluorescent dye can be used, suitably the fluorescent dye molecules are chosen from the group comprising PBD, Bis-MSB, 3-3'-diethyloxycarbocyanine-iodide and cresyl violet 670 perchlorate.

The magnitude of the fluorescent light emitted from a fibre is given by the equation $Aa/Ae = 2L/r$ wherein Aa is the surface area of the fibre and Ae is the area at which the fluorescent light is emitted.

In a preferred embodiment the radius of a fibre is between 0.25 and 0.70×10^{-2} meters and the length of the fibre is between 0.2 and 1.6 meters.

Clearly the dimensions of the fibres will depend on their use in proposed displays.

The invention also provides the use of the fibres as display pixels where artificial ambient light or sunlight provide excitation sources.

The invention further provides display devices comprising a plurality of fibres as described herein.

The plurality of fibres may include fibres to emit a variety of colours.

The devices may further comprise shutters to control emission from the individual fibres in a device.

DESCRIPTION

As a first example of the invention, Figure 1 describes the schematical diagram of a polymer-(fluorescent dye) optical fibre which shows the principle of operation for light generation and waveguide effect.

The polymer is an optically transparent one such as PMMA, polycarbonate, or polystyrene. In general, any transparent polymer can be used. The advantage of using polymers as fibre materials as opposed to glass is that they are lighter and more flexible. Also polymers can be moulded easier into the required shape than glasses.

The polymer host material contains the organic fluorescent dye molecules. Suitable materials for fluorescent dye molecules are some of the highly efficient materials such as;

a) PBD, (2-(biphenyl)-5-(4-tertbutylphenyl)-1,3,4-oxadiazole, for blue light emission

b) Bis-MSB, p-bis(o-methylstyryl) benzene for blue light emission

c) 3-3'-Diethyloxycarbocyanine-iodide for green light emission,

d) Cresyl Violet 670 Perchlorate, (5-imino-5H-benzol(a)phonoxazin-9-amine momnoperchlorate for red light emission

These dyes have nearly 100% quantum efficiencies for light generation. However, in general, any organic fluorescent dye can be used.

Light from ambient enters into the fibre because it is arriving from the optically less dense side (air) and is absorbed in the fluorescent dye molecules. A significant part of the emitted fluorescent light from the dye molecules is trapped within the polymer due to the wave

guiding effect (determined by the angle of total internal reflection) in the optically more dense material. Consequently the fluorescent light generated and waveguided inside the optical fibre can be directed toward the end of the fibre and utilised for illumination or display.

The amount of lightly emitted at the end of the optical fibre depends on the geometry of the fibre and the concentration of the dye within the polymer. The ambient light which is used to excite the dye is collected over the surface of the polymer fibre and the fluorescent light is waveguided and emitted at the two ends of the optical fibre. Therefore the magnitude of the fluorescent light generated is proportional to the total surface area of the fibre (at a given dye concentration). The surface area of the fibre A_a is given by;

$$A_a = 2r\pi L \qquad [1]$$

Aa

where r is the radius of the fibre and L is the length of the fibre.

The area at which the fluorescent light is emitted A_e is given by;

$$A_e = r^2\pi \qquad [2]$$

Ae

where r is the radius of the fibre.

Therefore, for a give dye concentration, the magnitude of the emitted light flux P_1(watt/cm^2) at the end of the fibre is proportional to the ratio of;

$$A_a/A_e = 2L/r \qquad [3]$$

Aa Ae

According to Eq. [3], the magnitude of the fluorescent light generated from the ambient light is proportional to the length of fibre and inversely proportional to the radius of the fibre.

As an example, Figure 2 shows the optical spectrum (fluorescent light intensity as a function of wavelength) for a polymer(dye) optical fibre, having a radius of 0.45×10^{-2} meter (0.45 mm) and a length of 1 meter collecting light from the ambient (office lighting) and emitting light in the green part of the optical spectrum. Figure 3 shows the comparison of the optical spectra for the ambient light and the same green optical fibre as in

Figure 2. It can be seen that by selecting the appropriate dye in the polymer fibre, the colour of the

emitted light can be very selective as opposed to the white light conditions in the ambient light.

As an example, the total optical power density of the ambient light (for the visible part of the spectrum under typical office illumination conditions) is 1.78×10^{-3} Watt/cm^2 and the total optical power density of the green fluorescent light generated at the two ends of a 1 meter length fibre (radius 0.45×10^{-2} meter) is 7×10^{-3} Watt/cm^2. This light power density (produced in the "selected" green part of the visible light spectrum) is much larger than the total optical power density for the ambient white light and therefore can be easily distinguished from it.

Therefore the light emitting pixels (using the end of the polymer fibres can be utilised as display pixels for a range of applications including road side displays (using sunlight as excitation source), information displays inside buildings (with artificial ambient light conditions) or information displays in open air venues.

By changing the dye in the polymer matrix, the colour of the fluorescent light can be tuned into red, green or blue i.e. full colour displays consisting of primary red, green and blue light emitting pixels can be fabricated.

The contrast between the amount of fluorescent light emitted from the polymer fibre and the total power of ambient light remains constant (as opposed to traditional displays using electrical power), and therefore displays based on light emitting fluorescent fibre pixels can be used either in direct sunlight or dimmed light conditions, without any change of the contrast.

It is also important to note that the green fluorescent light power density (7×10^{-3} Watt/cm^2) is also much larger than the corresponding green light power density produced by a CRT (Cathode Ray Tube) in a conventional computer screen (1×10^{-4} Watt/cm^2). In other words, the light emitting polymer fibre pixels can produce a light power densities (at different colours) for display purposes which are 70 times brighter than the CRT.

Figure 4. shows that by selecting another dye, the colour of the emitted fluorescent light at the end of the fibre can be changed from green (Figure 2.) to yellow.

By applying an electro-mechanical shutter or a liquid crystal based electro-optical shutter (using nematic, ferroelectric or cholesteric liquid crystals or liquid crystal-polymer composites) at the end of the individual fluorescent light emitting pixels an electro-optical display can be build to display information without the need to supply electrical power to the pixels for light generation and therefore a considerable saving in electrical energy can be achieved.

As an example, Figure 5. shows a schematical structure of a display unit which can be used for display applications.

SUMMARY

In summary, this invention describes a particular device (or device technology) which can be used to make novel types of displays or illumination units by using ambient light for generation of fluorescent light and collecting the fluorescent light by waveguiding.

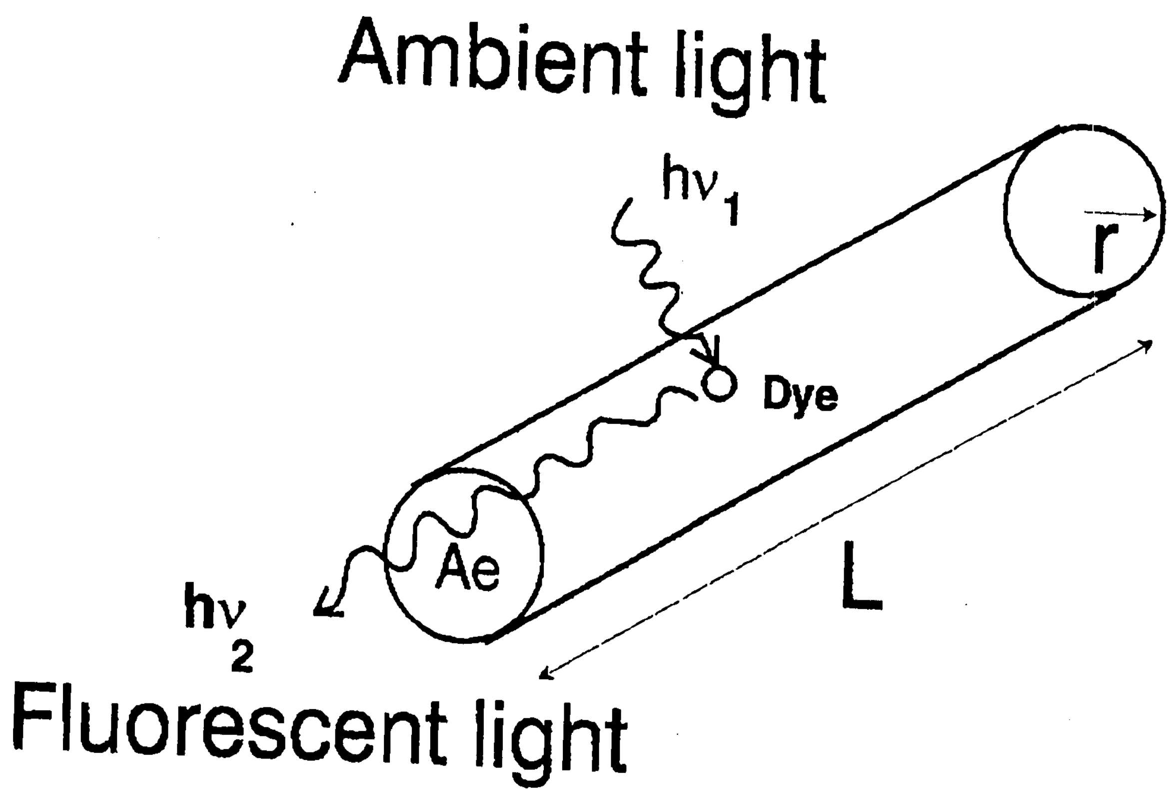
ADVANTAGES

The fluorescent light emitting polymer fibres use ambient light for excitation therefore do not require external electrical power.

The optical power density from the fluorescent optical fibre is higher than the optical power density of the ambient light. The ratio between these optical power densities does not depend on the ambient light conditions.

Figure 1

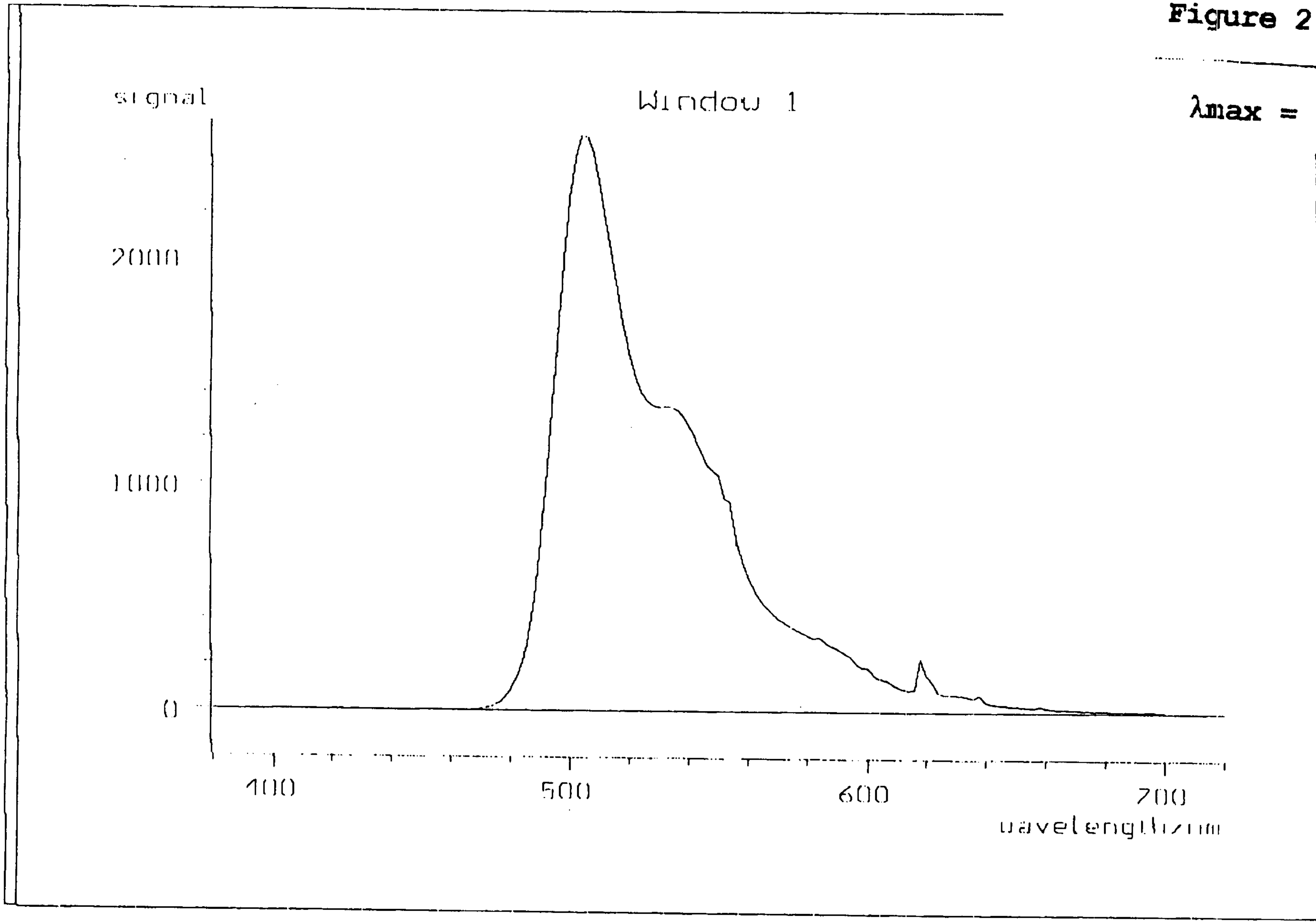
Fluorescent dye doped polymer optical fibre waveguide



Green fibre (0.9 mm diameter).

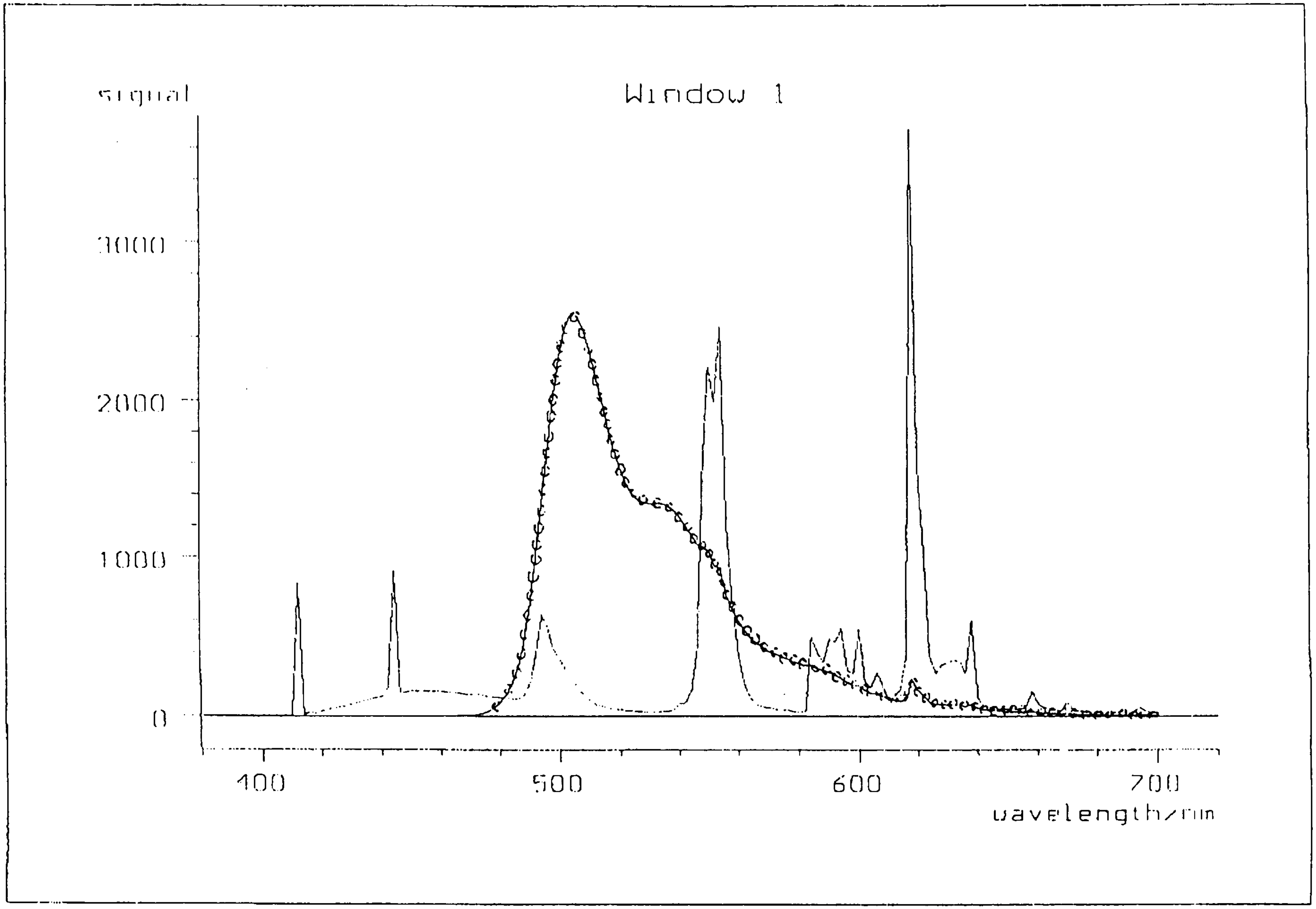
Figure 2.

λmax = 505 nm



Figure

Comparison of ambient light with green fibre (0.9 mm diameter).



Green fibre = black line.
Ambient light = red line.

Figur

Yellow fibre (0.9 mm diameter).

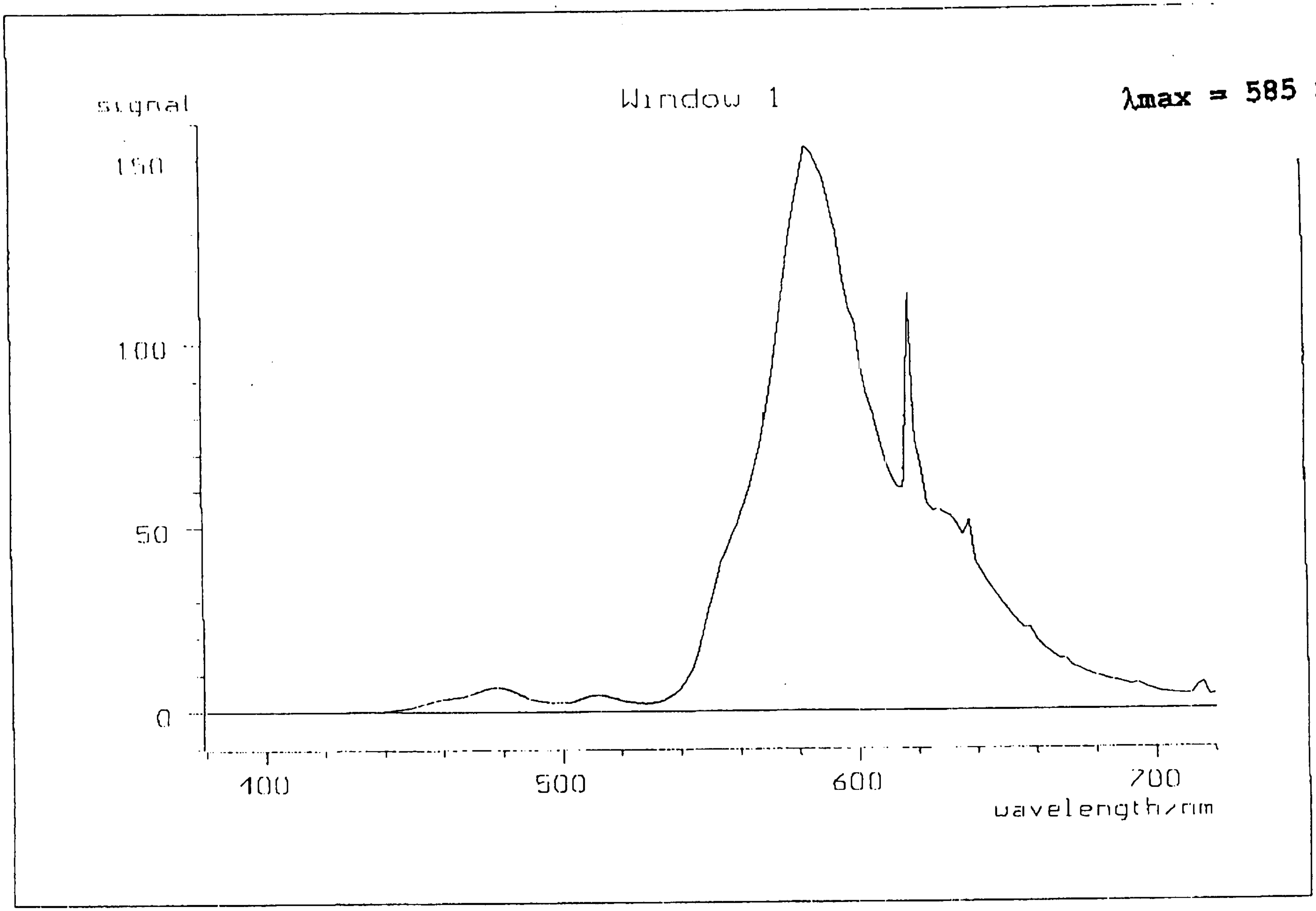


Figure 5.

Structure of display unit